"On the Correlation of the Mental and Physical Characters in Man. Part II." By ALICE LEE, D.Sc., MARIE A. LEWENZ, B.A., and KARL PEARSON, F.R.S. Received November 3,—Read November 20, 1902.

(1.) In a first paper on this subject* we gave a brief account of our material—Miss Beeton's copies of the Cambridge anthropometric measurements with degrees added at the University Registry, and the school measurements carried out by assistance from the Government Grant Committee. This material will take years to exhaust, but the present notice gives further conclusions to be drawn from Dr. Lee's and Miss Lewenz's later reductions from this great mass of raw statistics.

(2.) In the first place we may refer to certain matters which arise directly from the first paper. In the discussion which followed the reading of that paper it was suggested that we ought not to correlate intelligence with absolute measurements on the head, but with their ratio to the size of the body. The answer made on that occasion was based on data not then published, namely, that there is no sensible correlation between intelligence and the absolute size of the body. Hence the correlation between intelligence and any ratio of body lengths must also be small. To show this algebraically let x_1 and x_2 be any two measurements, and $R_{x_1x_2}$ the ratio x_1/x_2; let $r_{y_1y_2}$ denote the coefficient of correlation of any two characters y_1, y_2; let v_x be the coefficient of variation of the quantity x, *i.e.*, be 100 times its standard deviation divided by its mean.† Then we have the following formulæ‡ :—

$$v^2_{R_{x_1x_2}} = v^2_{x_1} + v^2_{x_2} - 2r_{x_1x_2}v_{x_1}v_{x_2} \quad \text{..... (i),}$$

$$r_{iR_{x_1x_2}} = \frac{v_{x_1}r_{ix_1} - v_{x_2}r_{ix_2}}{v_{R_{x_1x_2}}} \quad \text{..... (ii),}$$

where i denotes intelligence and x_1, x_2 any other characters.

Clearly when r_{ix_1} and r_{ix_2} are both small $r_{iR_{x_1x_2}}$ cannot be large. Let L be length of head, B be breadth of head, and S be stature. Then in the case of the Cambridge graduates

$$v_L = 3{\cdot}1839, \qquad r_{LS} = 0{\cdot}2816, \qquad r_{iL} = 0{\cdot}0861,$$
$$v_B = 3{\cdot}2836, \qquad r_{BS} = 0{\cdot}1529, \qquad r_{iB} = 0{\cdot}0450,$$
$$v_S = 3{\cdot}6958, \qquad r_{LB} = 0{\cdot}3448, \qquad r_{iS} = -0{\cdot}0056.$$

* "On the Correlation of Intellectual Ability with the Size and Shape of the Head," 'Roy. Soc. Proc.,' vol. 69 (1902), pp. 333—342.

† 'Phil. Trans.,' A, vol. 187, p. 276.

‡ *Ibid.*, p. 279. (ii) is deducible by simple algebra in the method often indicated in this series of papers.

The v's and the physical correlations are due to Dr. W. R. Macdonell,* r_{iL}, r_{iB} were given in our first paper,† and r_{iS} was deduced from the following fourfold table:—

(A.) *Intelligence.*

		Honours.	Pass.	Totals.
Stature.	Over 69″	244	228·5	472·5
	Under 69″	280	258·5	538·5
	Totals	524	487	1011

If r_{iS} were really sensible, it would mean that honours men were slightly shorter than pass men. The only safe conclusion we can draw, however, is that stature is not correlated with place in degree examinations.

From the above results we find

$$v_{R_{SL}} = 4{\cdot}1435, \qquad v_{R_{SB}} = 4{\cdot}5530.$$

Hence we have

$$r_{iR_{SL}} = 0{\cdot}0712, \qquad r_{iR_{SB}} = 0{\cdot}0370.$$

That is to say, the correlations of intelligence with the ratios of length and breadth of head to stature are slightly smaller than the correlations of intelligence with the absolute head-measurements. The result predicted from the smallness of r_{iS} in the discussion on the paper here receives its exact numerical confirmation.

(3.) Since our school measurements were started, MM. Vaschide, and Pelletier have published in the 'Comptes Rendus'‡ a statement that although unable to find any relation between intelligence and length or breadth of head, they consider a relationship to hold between intelligence and the auricular height of head. Their process was of the following kind. They asked the school teacher to select ten intelligent and ten non-intelligent children, and then measured the heads of these two sets, and found their means. This was done for groups of three ages in boys and two ages in girls. The probable errors of the difference of the means of ten observations are not considered, and by exactly the same process that they reason that the auricular height is greater for the more intelligent children they might have deduced from their statistics that intelligent girls of 11 years have lower heads

* 'Biometrika,' vol. 1, pp. 188-9.

† 'Roy. Soc. Proc.,' vol. 69, pp. 335-6.

‡ 'Comptes Rendus,' Paris, vol. 133, 1901, pp. 551—553.

than intelligent girls of 9 years, and non-intelligent boys of 11 years lower heads than the same class of 9 years! Frankly, we consider that the memoir is a good illustration of how little can be safely argued from meagre data and a defective statistical theory.

Taking from our school data the auricular height of 2005 boys, and from the growth table based on the same material, reducing them to the age 12 as standard, we find

(B.) *Auricular Height of Head and Intelligence.*

		Intelligent.	Slow.	Totals.
Height.	Above 127 mm.	481·5	584·0	1065·5
	Below 127 mm.	415·0	524·5	939·5
	Totals	896·5	1108·5	2005

Whence the correlation = 0·0161.

There is thus less correlation between auricular height and intelligence than between either breadth or length and intelligence; indeed, it is less than the probable error, and no weight can be laid on it whatever. The discovery of MM. Vaschide and Pelletier that the auricular height of school children is related to their intelligence seems to us quite incorrect for English boys, and unproven owing to defect of material and method even for French children.

It has been suggested by a sweeping critic, who clings to the *high* correlation of intelligence and head size, that our school head-measurements are of no value. To this we can only reply that in all cases where the measurements have been in the least doubtful the spanner has been returned and the measurements re-made. Further, if the absence of correlation between intelligence and head-measurements be a proof that the head-measurements have been taken badly or the scale of intelligence wrongly applied, how does it happen that high correlation comes out for the head-measurements of brothers, for all three cases, breadth, length, and height, and that its value is quite in keeping with the correlation between the intelligence of brothers? The existence of careless measurement or appreciation would have reduced these correlations also to near zero, as well as those on the characters on the *same* individual. We are forced to conclude that while our data give surprisingly consistent and uniform results for collateral heredity when we deal with upwards of twenty characters,* about half mental

* Results for seven mental and three physical characters were given in 'Roy. Soc. Proc.,' vol. 69, p. 155. These numbers have been more than doubled since that paper was published.

and half physical, they give with an equal weight the definite result that there is no *marked* correlation between intelligence and the size or shape of head in children.

(4.) While it seems desirable later to investigate specially the Cambridge data from the standpoint of the subject studied, as well as degree taken, we complete at present the list of other physical correlations with intelligence on the simple basis of honour and pass degree groups.

The following are the tables :—

Intelligence and Strength of Pull.

(C.) First Grouping.

Pull.	Honours.	Pass.	Totals.
Above 84 lbs.....	251	256·5	507·5
Below 84 lbs.....	273	229·5	502 5
Totals	524	486	1010

(D.) Second Grouping.

Pull.	Honours, 1st class.	Honours, 2nd, 3rd classes, and Pass.	Totals.
Above 84 lbs.	75	432·5	507·5
Below 84 lbs.	78	424·5	502·5
Totals	153	857	1010

Intelligence and strength correlation is from the first grouping $-0{\cdot}0765$, and from the second $-0{\cdot}0199$. Thus it would appear that from either grouping the honours men have slightly less strength of pull than the pass men, but as even this small amount is decreased when we group the first class men only together, such inferiority as there is seems to lie in the second and third class honours men. Taking the average, we may say that there is a negative correlation of $-0{\cdot}0482$ between intelligence and strength of pull. The probable error of the result, about 0·035, shows that very little weight can be attached to it.

(E.) *Intelligence and Strength of Squeeze.*

Squeeze.	Honours.	Pass.	Totals.
Above 85 lbs.	236·5	227·5	464
Below 85 lbs.	282·5	255·5	538
Totals	519	483	1002

The correlation between intelligence and strength in this case $= -0{\cdot}0242$.

This result, although it is less than its probable error, is again negative.

(F.) *Intelligence and Sight.*

This is judged in the Cambridge Anthropometric Laboratory by the distance at which the test type can be read.

Sight. Right eye.	Honour.	Pass.	Totals.
Over 61″	259·5	239	498·5
Under 61″	249·5	223	472·5
Totals	509	462	971

Forty-one men on our cards were unclassed—10 in 1st class, 5 in second, 1 in third, and 25 poll-men. This was possibly due to defective sight, or even to the loss of the right eye, because the strength of the left eye was sometimes given; we have not ventured to group these unclassed cases, however, with the short-sighted division.

The correlation between intelligence and long sight $= -0{\cdot}0049$. This is far less than the probable error of the result, but is again negative.

(G.) *Intelligence and Weight.*

Weight.	Honours.	Pass.	Totals.
Over 10 st. 13 lbs...	258·5	226	484·5
Under 10 st. 13 lbs.	265·5	261	526·5
Totals	524	487	1011

The correlation between intelligence and weight $= 0{\cdot}0459$, and is thus very slightly larger than its probable error.

Now, it has sometimes been argued that in any investigation of this kind, it is desirable to take not absolute weight, but its ratio to stature or some power of stature. Let W = weight, S = stature, and n = any power; let $R_n = W/S^n$, and v be a coefficient of variation, and r one of correlation, i standing for intelligence.

Then

$$v_{R_n}^2 = v_W^2 + n^2 v_S^2 - 2n v_W v_S r_{SW} \quad \ldots\ldots\ldots\ldots \quad \text{(i)},$$

$$r_{iR_n} = \frac{v_W r_{iW} - n v_S r_{iS}}{v_{R_n}} \quad \ldots\ldots\ldots\ldots \quad \text{(ii)}.$$

But

$v_S = 3{\cdot}6958$, $r_{SW} = 0{\cdot}4860$,

$v_W = 10{\cdot}8300$, $r_{iW} = 0{\cdot}0459$,

$r_{iS} = -0{\cdot}0058$,

from results already given for the Cambridge data. Hence, calculating v_{R_n} from (i) for $n = 1$, 2, and 3, we deduce

r_{iR_1} = correlation of intelligence with ratio weight to stature = 0·0540,

r_{iR_2} = ,, ,, ,, (stature)^2 = 0·0555,

r_{i_3R} = ,, ,, ,, (stature)^3 = 0·0503.

There is no substantial difference between any of these correlations and that for intelligence and absolute weight. As they were found indirectly by formulæ, it seemed desirable to test at least one of them directly. Accordingly Miss M. Beeton found the ratios of weight per inch of stature for 1012 Cambridge men. The resulting table was as follows:—

(H.) *Intelligence and Weight per inch of Stature.*

	Honours.	Pass.	Totals.
Over 2·224 lbs. per in.	258·5	222	480·5
Under 2·224 lbs. per inch ..	265·5	266	531·5
Totals.....	524	488	1012

The distribution is sensibly the same as that of the table for absolute weights, and the correlation comes out 0·0604, *i.e.*, it differs only by 0·0064, or about one-fifth of the probable error from the value of the correlation obtained indirectly.

We may then, I think, conclude that whether we take absolute weights or the ratio of weight to stature, honours men are slightly heavier than poll-men. Summing up the whole of our examination thus far of the Cambridge measurements we may say that:

The honours men, and presumably therefore the more intelligent class, are slightly heavier and have slightly longer and broader heads; they are not quite as tall nor as strong, whether strength be measured by pull or squeeze, and are slightly shorter-sighted than the poll-men, or presumably the less intelligent class. In no single case, however, is the correlation between intelligence and the physical characters sufficiently large to enable us to group the honours men as a differentiated physical class, or to predict with even a moderate degree of probability intellectual capacity from the physical characters of the individual.

(5.) While the above and the previously published results exhaust the Cambridge data, as long as we preserve the division into honours and poll-men, much more remains to be done on this material when we consider subject groupings among the Cambridge graduates, or when we turn to the much wider range of both physical and mental characters recorded in our school measurements.

A preliminary inquiry may, however, be recorded here as bearing upon a rather vexed question at the present day, namely, the relation of athletics to health and intelligence. In our school measurements we had three categories: Health—divided into the classes: *Very Strong,* Strong, Normally Healthy, Rather Delicate, Very Delicate.* Ability or Intelligence—was divided into six classes: *Quick Intelligent, Intelligent, Slow Intelligent, Slow, Slow Dull, Very Dull.*

Lastly, we had the alternative category—*Athletic, Non-athletic.* By *Athletic* we understand not only fondness for out-door exercises and games, but good performance in them. There was a control entry in the schedules under the heading *Games or Pastimes*, in which not only what the children *liked*, but in addition what they were *good at*, had to be entered. We were thus in a position to make that triple correlation between health, ability, and athletic power, which seems really needful, if a sane judgment is to be made on the part athletics should play in the school curriculum.

The following tables give the relations between health and ability, ability and athletic power, and health and athletic power:—

(I.) *Health and Intelligence.* 2253 *Boys.*

Health.	Quick intelligent, intelligent.	Slow intelligent, slow, slow dull, very dull.	Totals.
Very strong, strong..	415	453	868
Normally healthy ...	461	542	1003
Rather delicate, very delicate.....	128·5	253·5	382
Totals	1004·5	1248·5	2253

* *Strong* in these categories equals *robust.*

The correlation dividing at the *Strong* is 0·0820.

The mean of the other divisions (i) dividing at the *Delicate*, and (ii) putting the *Slow Intelligent* with the *Intelligent*, gave 0·0835. We conclude, therefore, that there is a sensible, but not marked correlation between good health and intelligence.

Taking, however, health and athletics we have the table :—

(J.) *Health and Athletics.* 1743 *Boys.*

	Very strong.	Strong.	Normally healthy.	Rather delicate.	Very delicate.	Totals.
Athletic ...	91	447·5	497·5	120	3	1159
Non-athletic	9·5	98·5	293·5	166·5	16	584
Totals	100·5	546	791	286·5	19	1743

The correlation between healthy and athletic dividing between *Strong* and *Normally healthy* is = 0·4570, a very marked relationship.

Next, taking intelligence and athletics, we find :—

Intelligence and Athletics. 1708 *Boys.*

	Quick intelligent.	Intelligent.	Slow intelligent.	Slow.	Slow dull.	Very dull.	Totals.
Athletic ...	159·5	421·75	355·5	158·75	40·5	12	1148
Non-athletic	46	163·25	187·5	99·75	48·5	15	560
Totals	205·5	585	543	258·5	89	27	1708

Dividing between intelligent and slow intelligent we find the correlation between intelligence and athletic character is 0·2133.

This result may be exhibited also in the percentages of athletic and non-athletic boys who fall under each class of intelligence :—

Percentages of Athletic and Non-athletic Boys under each grade of Intelligence.

	Quick intelligent.	Intelligent.	Slow intelligent.	Slow.	Slow dull.	Very dull.
Athletic ...	14	37	31	13	4	1
Non-athletic	8	29	32	18	9	3

The relationship between keenness for combined with capacity in games and general intelligence is here manifest.

Certain other correlations with the athletic character may be just noticed without giving the tables. The athletic boy is popular (0·3250) and noisy (0·3452), and this although popularity is not found to be directly correlated with noise. He is slightly self-conscious (0·0761), and is more likely to be fair than dark (0·0391). His temper tends to be quick rather than sullen (0·2207), as the following table, based on 1664 cases, will show :—

Percentages of Athletic to Non-athletic Boys for each Temper.

	Quick tempered.	Good-natured.	Sullen.
Athletic	21	68	11
Non-athletic.....	12	74	14

To sum up, then: While the intelligent are only *slightly* the more healthy, the athletic are *notably* the more healthy element in the community. Further, the athletic are considerably more intelligent than the non-athletic; they are the more popular and more noisy element; and they tend to quick rather than sullen temper. We may in general terms describe the athletic boy as healthy, quick-tempered, and intelligent when compared with the non-athletic boy. He certainly under all three headings should make a better soldier than the non-athletic, and it is hard to discover any statistical evidence in *school* life for such expressions as "the flannelled fool at the wicket," or "the muddy oaf at the goal." What happens in later life can only be determined when ample statistics are available for reduction and comparison. Failing such data, we can argue only from the vaguest of impressions.